Electron cyclotron resonance ion source charge breeder studies for performance optimization

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Introduction

At the ISAC facility of TRIUMF, an electron cyclotron resonance ion source (ECRIS) is used for charge breeding of isotopes with A>30. In this research, a detailed modelling of the source magnetic fields and systematic investigation of the injection and extraction optics of the Charge State Booster (CSB) alongside its extraction and beam transport system was conducted for a better understanding of beam injection, formation and extraction of highly charged ions to improve the overall performance of the system under the regime of single and double frequency heating.

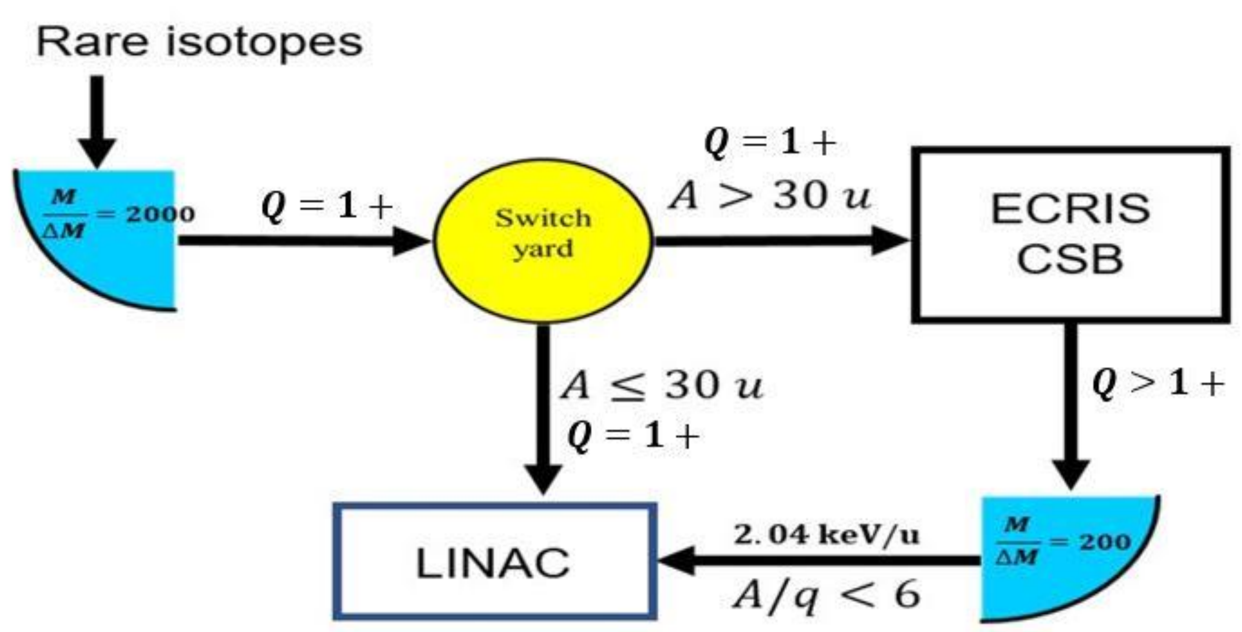

Fig. 1: Schematic of TRIUMF ISAC Facility

TRIUMF ECRIS uses electromagnetic waves and magnetic fields to produce and confine a dense plasma of energetic electrons and relatively cold ions. Injection and extraction are based on the three-electrode system. TRIUMF's in-house beam transport design code, TRANSOPTR, was recently used to completely model the injection and the extraction beamlines of the CSB for the first time (including the electric and magnetic fields in both the injection and the extraction regions). The optimized beam envelopes of the injected and extracted beams are shown in Figures 3 and 4, respectively.

TRIUMF ECRIS CSB

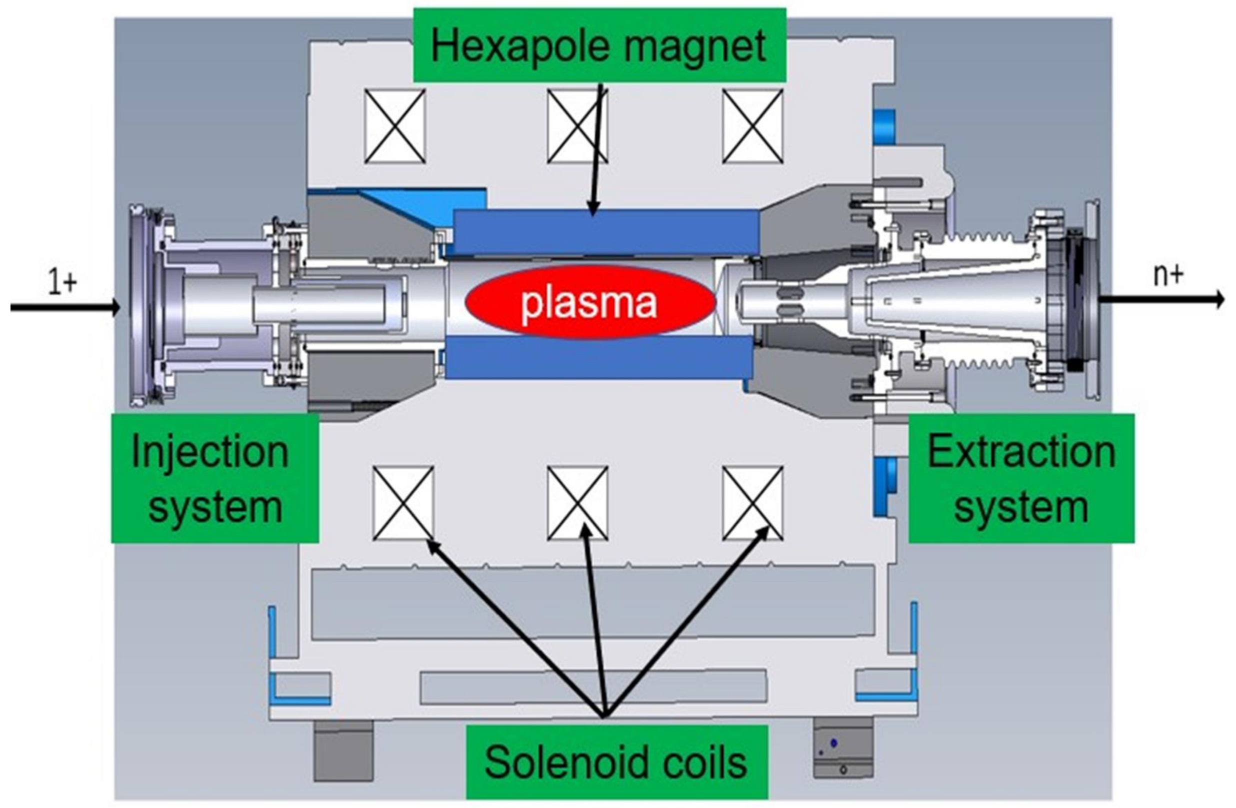

Fig. 2: TRIUMF ECRIS Charge State Booster

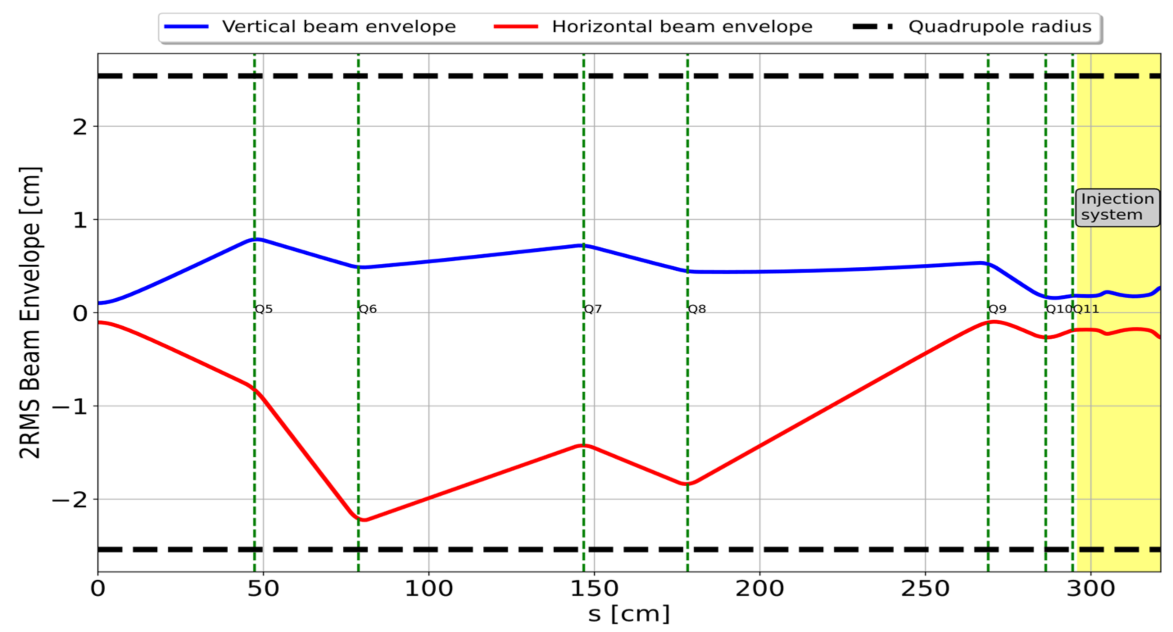

Fig. 3: Beam Envelope of the Cs+ Injected ions modelled in TRANSOPTR

To ensure that injected ions are efficiently captured by the ECR plasma, the relative potential between the Cesium ion source and the CSB was varied to determine the voltage that produces the maximum intensity of highly charged Cs ions. This technique serves as a simple method to determine the plasma potential. Figure 5 shows that the voltage at which the injected ions were efficiently captured is of the order of 16 V.

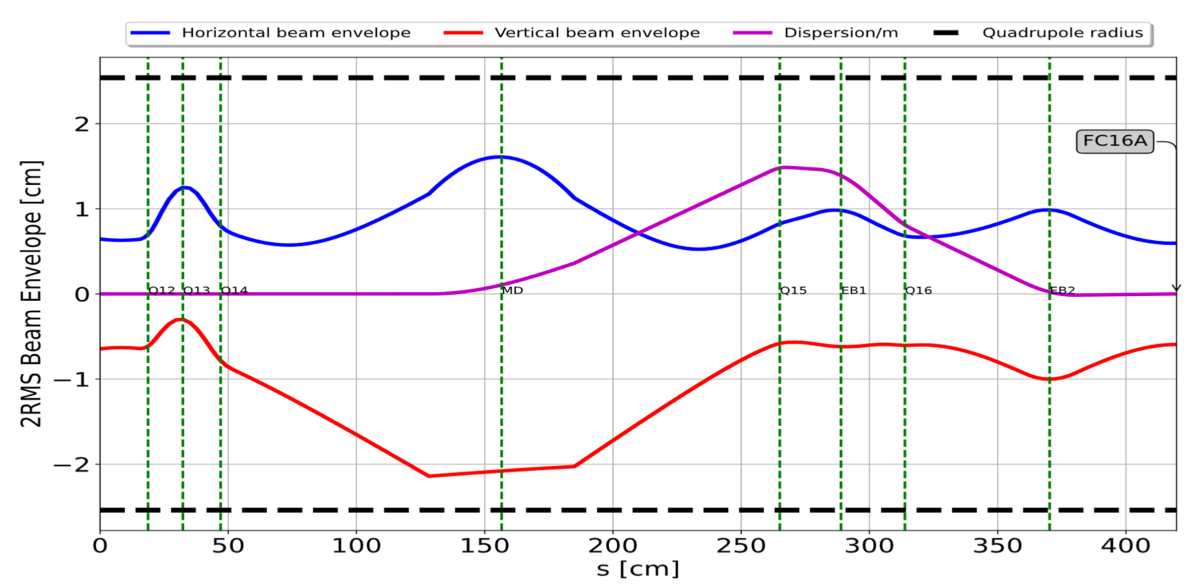

Fig. 4: Beam Envelope of the Extracted Cs24+ ion beam modelled in TRANSOPTR

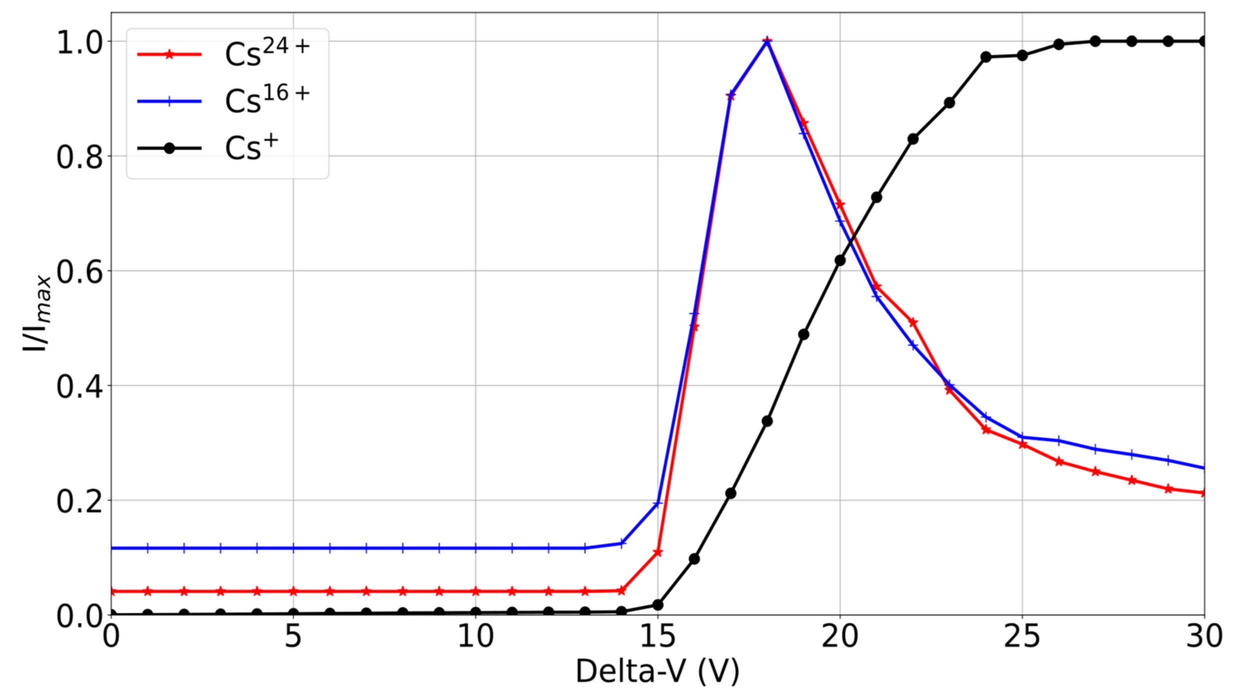

Fig. 5: Normalized Beam intensities of Cs+, Cs18+ and Cs 24+ versus the relative potential difference between CSB and Cs-source

Figure 6 compares the measured emittance of the CSB with the IGUN simulation. It shows the evolution of the emittance when the extraction field is varied between two 80 and 140 kV/m. Although the simulation does not agree with the measurement, the trend of the plot indicates that as the extraction field is varied, the plasma boundary is changed accordingly, which changes the beam emittance. The disagreement is attributed to the accuracy to model the plasma density, plasma constituent and the magnetic field in the extraction region in the simulation.

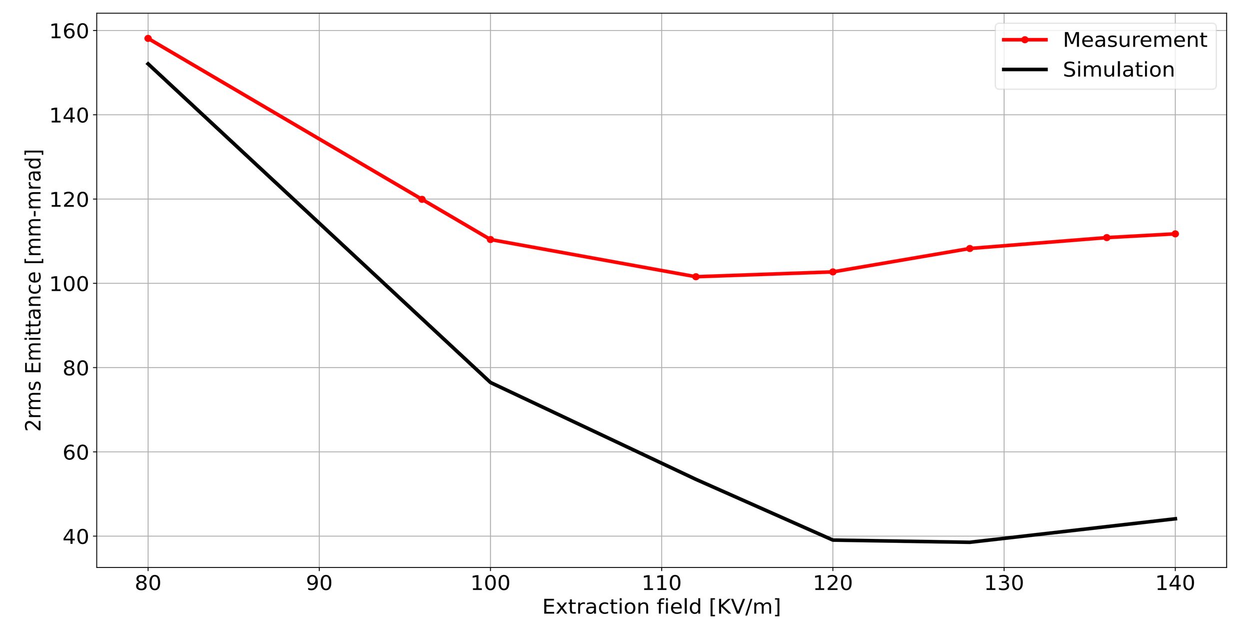

Fig. 6: The ECRIS CSB total Emittance vs Extraction Field

Figure 7 shows the mass spectrum of the CSB with and without Cesium. The peaks of the Cesium charge states are indicated by the arrows while the other peaks are from the residual ions.

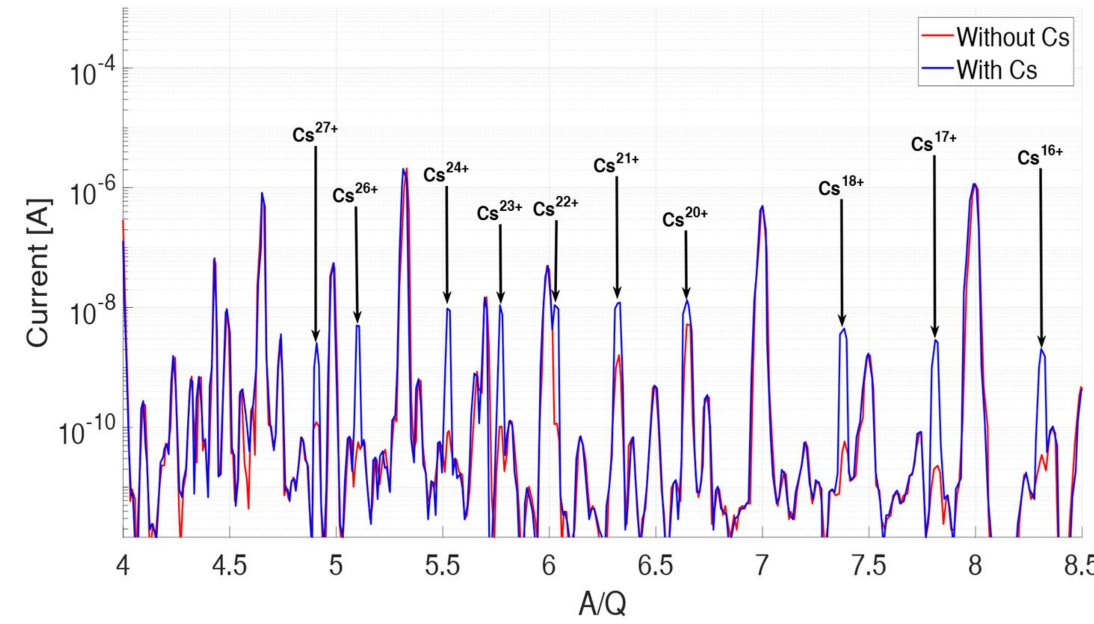

Fig.7: Mass Spectrum of the CSB with and without Cs

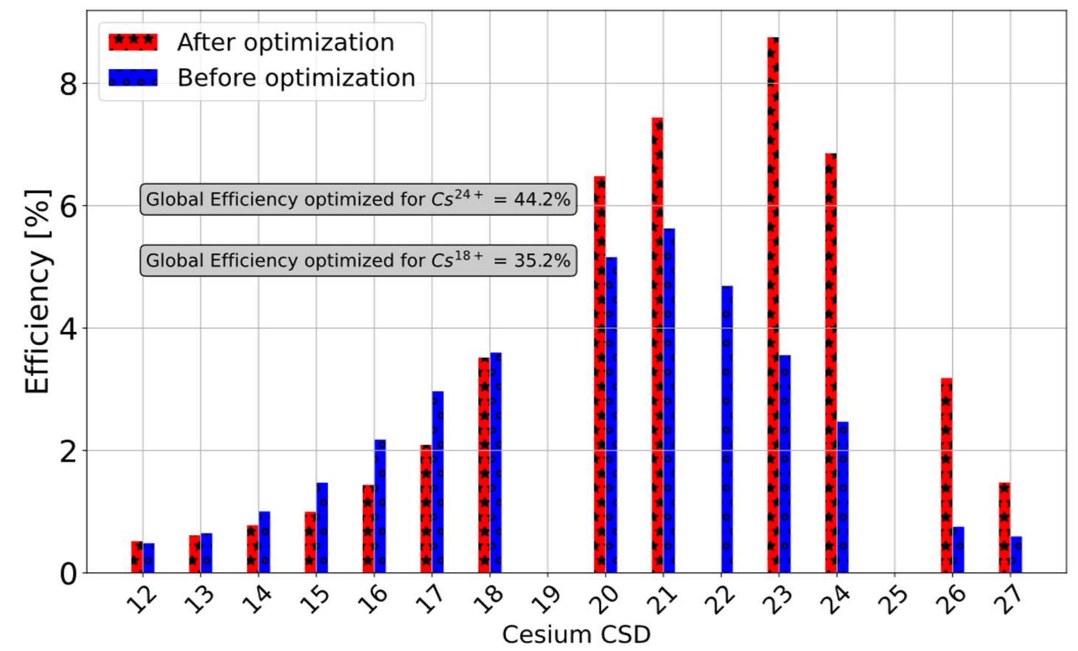

Fig.8: Efficiency of Cs Charge state between 12+ and 27+

Figure 8 compares the efficiency of the CSB before and after optimization. The peak of the Cs CSD shifted from 21+ to 23+ while the global efficiency increased from 35.2 % to 44.2 %.

Outlook

The final goal of this research works is to improve the overall performance of the CSB by implementing the superior two-frequency heating technique. The technique has been demonstrated to stabilize the plasma and increase the maximum charge state of the beam that can be produced in the ECRIS. The implementation is currently underway.

Acknowledgement

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Discovery, accelerated